OCT 02 1991

FINAL REPORT FOR:

PAPAFOX PROJECT 442

TITLE: **Development of Arctic Temperature PV Regulator**

Supply and Services Canada File No. 069SZ.23440-0-9463
Contract No. 23440-0-9463/01/SZ
Requisition No. 23440 0 9463
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AUGUST 16, 1991

Final Report - Task 5 to 7 - Preproduction Prototype for C.C.G/Final Report

A preproduction prototype has been completed with a redesigned sensor unit which has been included to resolve the anomally in the operation of the sensor unit during cold weather testing. A problem was identified as current leakage through grounding due to lack of insulation of the sensor unit originally utilized.

The unscheduled operation of the high voltage LED at ambient temperatures with the yellow LED as reported in the ORTECH report was resolved by the addition of capacitors for supply line decoupling close to the alarm circuit pins as suggested in the Milestone 2 report.

The final assembly package conforming to Canadian Coast Guard specifications is a stainless steel NEMA4 enclosure 14 x 12 x 8 inches with a hinged "clamp on" panelled door. The unit is designed for wall mounting and has an exterior heat sink for the dissipation of energy when the unit is in regulation mode. For the extreme temperature requirements of - 60 deg. C. to + 60 deg. C., a special silscon gasket has been used to replace the conventional neoprene.

There are a total of 7 LED indicators provided in the unit which provide the following information:

1. Green LED - "Normal charging" when the regulator is not operating and all the current is flowing into the battery/load. 2. Yellow LED - "Normal regulation" when

24 pp

CONTRACT SERIAL NO. 23440-09463-01-SZ

CONTRACTOR: PAPAFOX LTD.

REQUISITION NO. 23440-0-9463

MICROMEDIA

power is being diverted away from the battery/load.

3. Red LED 1 - "High Volt" alarm which will only operate if the battery voltage exceeds regulation voltage by a preset amount. This may be taken to be e "Regulator fail" alarm also. The high volt alarm set point is adjusted by a variable resistor.

4. Red LED2 - "Low Volt" alarm - will operate if the battery voltage sinks below a preset level. This may be caused by a variety of reasons, such as an extended period of low sun light, excessive lode consumption, array or battery failure. The "Low Volt" alarm set point is adjusted by another variable resistor.

5. Red LED3 - This LED is illuminated to indicate a reverse polarity connection from the battery and will light up if the battery is hooked up incorrectly.

On the Fail Safe Assembly Board:

6. Red LED4 - "Fail Safe in Operation" - this indicates that the Fail Safe Circuit is currently operating. This circuit automatically resets.

7. Red LED5 - "Fail Safe Operated" - which shows that the Fail Safe has operated at least once while the system has been unattended. This circuit latches and is manuallly reset by a switch because the red LED 4 resets automatically the red LED 5 confirms that the LED 4 has been activated since the unit was last manuallly reset.

The extendable features on the alarm circuits provide a ready method of providing a low voltage cut-off facility for the load if desired. This extendable feature enabling the alarms to be connected to other external devices allows for a number of other options for monitoring or control purposes.

A copy of the operations manual including the specification sheet is attached as Appendix A to this report.

While this prototype unit is designed for a 60 watt or 5 amp PV system, the components and circuit design are such that by replacing the heat sink and resistor with higher capacity units, up to 300 watt or 25 amps could

be handled. This flexibility is useful for providing a range of models with larger capacities to the market place.

The completed prototype unit has been forwarded to the Canadian Coast Guard for evaluative purposes.

OCT 02 1991

DRAFT

PV ARCTIC REGULATOR

MODEL SL12V5

OPERATIONS MANUAL

Prepared By:

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PV ARCTIC REGULATOR
Model SL12V5

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PRODUCT DESCRIPTION

PHOTOVOLTAIC CHARGER REGULATOR FOR ARCTIC USE
MODEL SL12V5

1.0 GENERAL DESCRIPTION

This regulator is a stand alone photovoltaic system charge controller designed to function reliably in extreme cold weather down to minus 50 degrees F. It is intended for a low power photovoltaic system that requires the ultimate in reliability and as such has a built in "Fail Safe" emergency board. Any malfunction of the regulator itself will result in the PV array being connected directly to the battery terminals so that any power produced by the array will still be fed to the battery.

The unit features L.E.D. indicator lights to confirm the mode of operation and/or the status of the fail safe circuit. A blocking diode is included to prevent current leakage through the array from the battery and the settings of the various alarms and control points are field adjustable.

Additionally the alarm functions are expandable in that field and connector outputs can be connected to transmission or recording devices. Another main requirement of such a regulator for reliable operation in extreme weather is the ability to adjust the regulation point in accordance with the temperature of the battery in order to maintain consistent charging current from the array over the complete temperature range of operation.

2.0 FEATURES:

The features of the unit include the following:

a. reverse polarity protection
b. reverse battery polarity light indicator
c. MOV lightning protection on inputs
d. blocking diode included
e. fail safe operation
f. fail safe operation active indicator
g. fail safe operation automatic reset
h. fail safe operation operated latching indicator

i. alarm indicator for high voltage
j. alarm indicator for low voltage
k. alarms functions extendable - open connector outputs for monitoring, radio transmission, horns, etc
l. fail safe alarms functions extendable
m. external battery temperature sensor
n. regulating voltage temperature compensator
o. separate battery current and battery voltage sensor cables.
p. external heat sink
q. field adjustable settings for
- regulating voltage start
- high voltage alarm
- low voltage alarm
- fail safe operating voltage

3.0 SPECIFICATIONS:

Voltage: 12 volts DC Nominal
Amps: 5 amps
Battery type: lead acid
Inputs: Temperature sensor +
Temperature sensor -
Battery current +
Battery current -
Battery voltage sensor +
Battery voltage sensor -
Array current +
Array current -

Waterproof gland entries for:

A.	Tempsense cables provided	16GA X 2
B.	Battery current cables	12GA X 2 SOW
C.	Battery voltage sense	16GA X 2
D.	Array Current cables	12GA X 2 SOW

Housing: Housing is a stainless steel NEMA4 enclosure for water and corrosion resistance with special silicone gasket for extreme operating temperatures of - 60deg. C. to + 60deg. C.

Wall Mounting type: - 4 - 5/16 " mounting holes - two on top and two on bottom 14 3/4 inch lower holes spaced 10 " apart.

Enclosure size: 355mm x 305 mm x 203 mm

Weight: Net: 20 lbs. (9 kg.)
Shipping: 37 lbs. (17 kg.)

Shipping Dimensions:

PAPAFOX LIMITED
4044 ABERDEEN ROAD
BEAMSVILLE, ONTARIO
L0R 1B6
Telephone 416 563 0539

MANUAL OF OPERATIONS

PV ARCTIC CONTROLLER MODEL SL12V5

1.0 GENERAL

This control is designed to regulate the charging current from a PV array into a battery through a wide range of temperatures to an extreme low of - 50 degrees C. As the battery storage unit becomes fully charged, the regulator will divert a portion of the current to a heat sink, decreasing the charging current to the battery. This enables a more complete charge of the battery to be achieved and protects the battery from overcharging with consequent shortening of battery life.

As the battery voltage reaches the full charge cut off point, the complete output of the array is diverted through the external heat sink in the full regulation mode.

As the battery voltage drops due to the consumption by the load, the array is then reconnected to the battery and the charging continues as the array generates the power.

The unit includes a fail safe board which in the unlikely event of a regulator malfunction, will insure that the array output is connected directly to the battery terminals by - passing completely the control circuit. This function is activated by a low voltage detection on the battery and is reconnected in the normal mode should the battery voltage again rise. When in the "fail safe" mode of operation, an LED light indicator is illuminated and additionally a latching relay continues to illuminate a second LED indicator even if the battery voltage again rises to a normal value. This feature not only enhances the integrity of the system but provides an indicator to the operating personnel that a low voltage condition has occurred. It is manually reset by a reset button.

2.0 INPUTS:

Internal connection points are provided for the following inputs:

- battery current +
- battery current -
- battery voltage sense cable +
- battery voltage sense cable -
- battery temperature sense +
- battery temperatrure sense -
- array currrent +
- array current -

The load is connected directly to the battery for operation.

A reverse polarity connection of the battery is shown by an alarm LED 3 being illuminated.

The circuit is protected against reverse polarity connection of the array by an internal diode.

The system wiring diagram indicates the connections for the regulator inputs. The battery sense cables go to BS- and BS+ the temperature compensation cable go to the TC- and TC+ (BROWN) terminals, the battery load cables go to the BY- and the BY+ terminals, and the array output is connected to the AY- and AY+ terminals on the main board.

There are a total of 7 LED indicator lights that function as follows:

GREEN	LED 1	lit during normal charging of the battery
YELLOW	LED 2	lit when the current is being diverted away from the battery in a regulating mode
RED	LED 3	lit when battery connected with reverse polarity
RED	LED 4	low voltage alarm
RED	LED 5	high voltage alarm
RED	LED 6	lit when "failsafe" circuit is currently operating
RED	LED 7	lit indicating the "failsafe" has operated since last being manually reset.

A reset button switch is provided to manually reset the "failsafe" latching circuit.

3.0 EXTENDING ALARMS:

Terminals are provided on the "failsafe" board to extend the "failsafe" alarm indicators to external devices if required. These are labelled OP1, OP2, and NEG.

4.0 ADJUSTMENTS:

The regulator and alarm set points can be modified by rotating the multi-turn potentiometers as follows:

RV1 - adjust the voltage at which the regulator begins to operate. This set voltage is modified according to the battery temperature by the temperature sensor.

RV2 - low volt alarm set point

RV3 - high voltage set point. This operates if the battery voltage exceeds the regulation voltage by a preset amount, this may also be taken to be a "regulator fail" alarm.

FSRV1 - on "failsafe" board - adjusts the voltage at which the "failsafe" circuit operates.

SW1 - This is the "failsafe" latching indicator reset button which turns off the LED7 "failsafe" operated indicator.

5.0 OPERATIONS:

The regulator is configured as a linear shunt type regulator, so that power not required for the battery/ load is diverted into a power resistor (heat sink). A blocking diode is included to prevent the battery discharging back through the power resistor.

In normal operation a green LED is lit indicating "normal charging".

When the battery is full and power is being diverted away from the battery a yellow LED is lit, indicating "normal regulation".

The voltage at which the regulator begins to operate is adjustable by RV1. The set voltage is then modified

according to the battery temperature detected by the battery temperature sensor. The adjustment is in accordance with the temperature compensation curve included in Appendix A.

Should the battery terminals be connected with reverse polarity, the LED3 is illuminated warning that the battery cables connection should be corrected by reversing them.

6.0 ALARMS:

Two alarm functions are provided and show as two LED indicators:

- "HIGH VOLTS" LED 5 will operate if the battery voltage exceeds the regulation voltage by a preset amount. This may be taken to be a "regulator fail" alarm also. The "high volts" alarm set point is adjusted by RV3.

- "LOW VOLTS" LED 4 will operate if the battery voltage sinks below a preset level. This may be caused by a variety of reasons, an extended period of low sun, excess load consumption, array or battery failure. The "LOW VOLTS" alarm set point is adjusted by RV2.

Each alarm may be extended in function by using the "Open collector" outputs also provided on the main board. These are labelled LVA, HVA, and COM.

7.0 FAILSAFE ASSEMBLY:

The "Failsafe Circuit" is wired in series with the regulator circuit so that if the regulator should fail to a short, the "Failsafe Ciruit" will open the shunt path and enable it to maintain continuous charging of the battery.

The voltage at which the "Failsafe" operates is adjustable by RV1. There are two red alarms LEDs on the "Failsafe" board which operate as follows:

- "Failsafe in Operation" which shows via LED6 that the FAILSAFE CIRCUIT is currently operating. This circuit automatically resets.

- "Failsafe Operated" which shows via LED6 that the

FAILSAFE has operated at least once while the system has been unatended. This circuit latches and is manually reset by the push button switch SW1.

Again the function of both alarms may be extended by using the open collector outputs provided on the "Failsafe Board" labelled OP1, OP2, AND NEG.

8.0 SYSTEM CONNECTION:

The eight input cables to the regulator should be connected in the following order:

1. The two temperature sensor cables to TC+ and TC-

2. The battery voltage sense cables from the battery to the BS+ and BS-

3. The main current battery connection to terminals BY+ and BY- .
   Check that LED3 (red) does not light, if it does reverse the BY+ and BY- cables.

4. Array cables to AY+ and AY-

Appendix A includes a general wiring diagram and component locations.

9.0 OPERATIONAL TESTS:

The test procedures to confirm the proper operation of the unit are included in Appendix B.

APPENDICES:

A - Temperature Compensation Curve
  - Wiring Diagram
  - Component Locations

B - Operational Test Procedures

C - Specifications

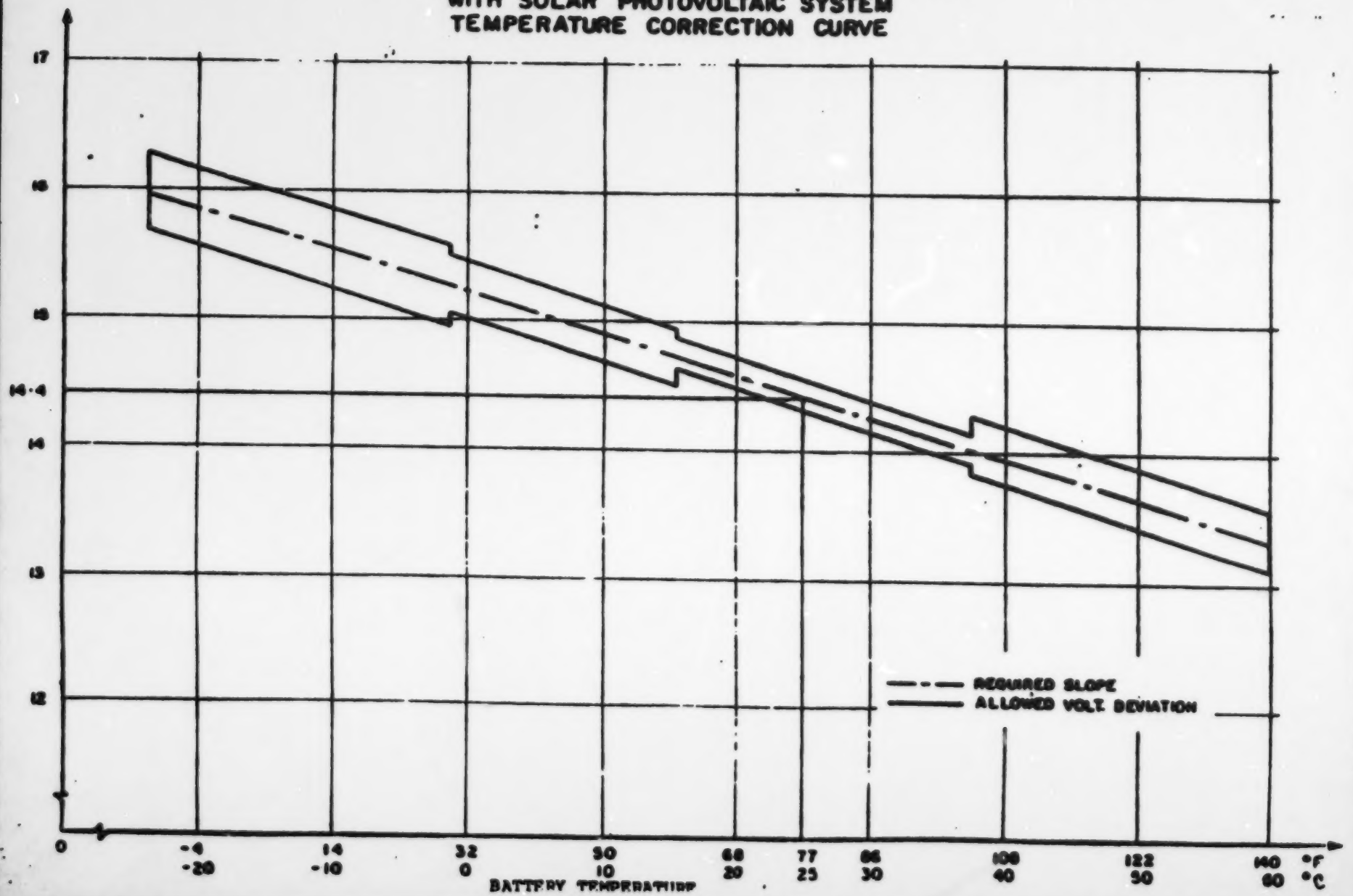
APPENDIX A

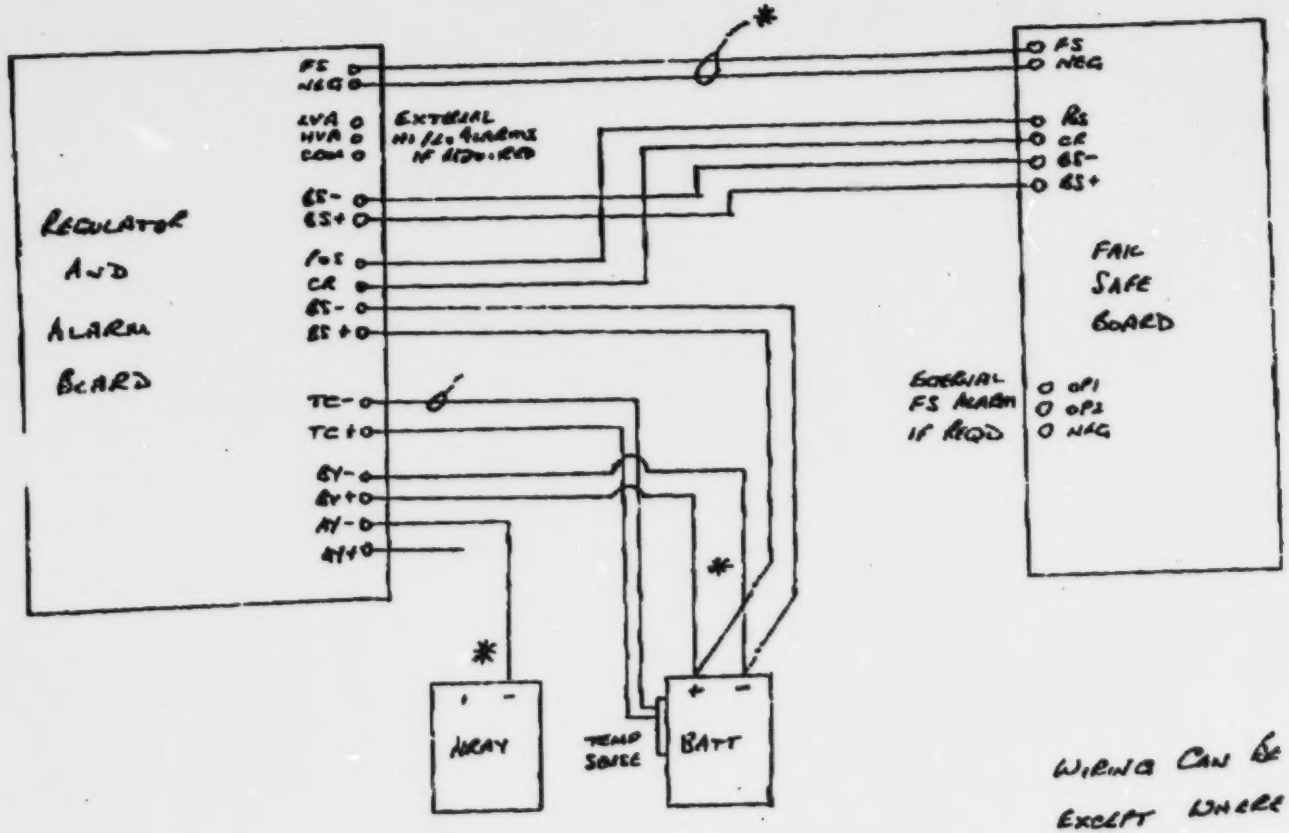
TEMPERATURE COMPENSATION CURVE

Wiring Diagram

Component Locations

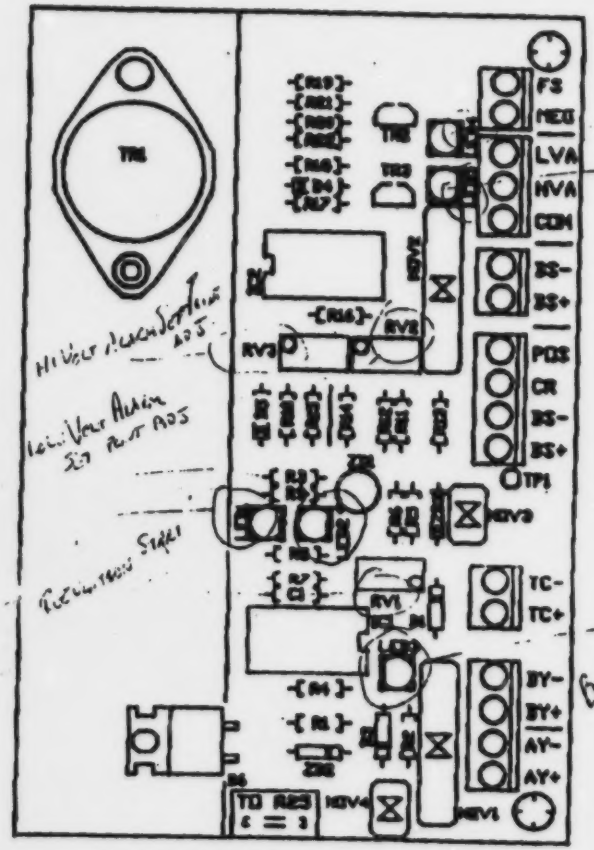
CANADIAN COAST GUARD
SHUNT TYPE REGULATOR USED IN CONNECTION WITH SOLAR PHOTOVOLTAIC SYSTEM TEMPERATURE CORRECTION CURVE





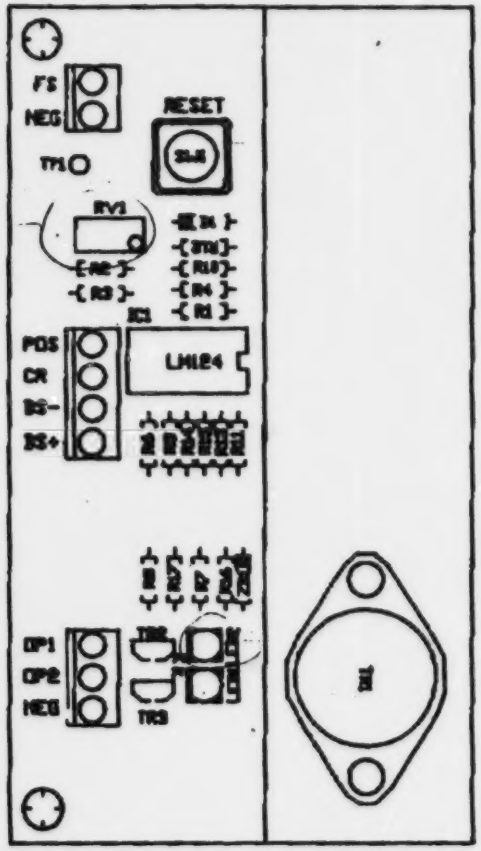
WIRING CAN BE LOW CURRENT EXCEPT WHERE SHOWN * WHICH MUST BE RATED FOR FULL ARRAY CURRENT

SYSTEM WIRING DIAGRAM.



							SOLAR REGULATOR PCB	DRN
								DATE
								CKD
							COMPONENT OVERLAY	APP'D
DATE	APP'D	HOLD No	DRN	DESCRIPTION	ISS	© 1991		DRG No.

VIEWED FROM COMPONENT SIDE



FAIL-SAFE PCB

COMPONENT OVERLAY

VIEWED FROM COMPONENT SIDE

DATE	APP'D	NCB No	DRN	DESCRIPTION	ISS

© 1991

DRN
DATE
CKD
APP'D
DRG No.

APPENDIX B

OPERATIONAL TEST PROCEDURES

APPENDIX B

DESCRIPTION OF OPERATION AND TEST

1.0 Description of Operation and Test

NOTE For test purposes the use of a mains/dc power supply with a variable output voltage in the range 0-30 Volts, which is current limited to the maximum array current is recommended. This is easier (and quicker) than taking the battery through a full charge/discharge cycle to check all the setting. One such power supply will be required to act as an electronic array.

In addition one low current power supply will be required to substitute for the battery for voltage setting checks.

Suitably rated and calibrated Voltmeter and Ammeter will be required.

1.1 REGULATOR

As the battery charges from the aray (or power supply), the battery voltage is sensed over the battery voltage sensing wires. The integrated circuit ICI/c compares the voltage setting from RV1 with the Reference Voltage generated by the combination of ZD1 and the Temperature Sensor connected to TC+ and TC-. During normal charging of the battery, LED1 (green) will be "ON".

As battery voltage rises to preset level, ICI/c turns TR1 'ON' and some current is diverted away from the battery through TR1 and the power resistor. Progressively more current is diverted away from the battery until the curremt flowing into the battery is just sufficient to hold the battery voltage at the preset level. During the time that current is being diverted away from the battery, LED2 (yellow) will be 'ON'. When the Yellow is 'ON", the Green will be 'OFF'.

Connect an Ammeter in series with the main battery current connection and charge the battery from the array or current limited power supply. Allow the battery to charge, check that the LED1 (green) is "ON" and that current is flowing into the battery.

Set RV1 to limit the maximium on charge voltage to the desired value "Vr" and check that LED2 (yellow) is "ON". Check that as the regulation setting is reached the current flowing into the battery decreases. During regulation the power resistor will become hot, this is normal. Check that the regulation setting 'Vr' can be adjusted with RV1.

1.2 ALARMS

The Battery Sense Voltage is fed to the alarm circuits formed by IC2/a-d, being a device containing four individual circuits, 1C2/b and c buffer the voltage setting of RV2 (Set Low Volts) and RV3 (Set High Volts). IC2/a and d apply temperature correction and drive the LED lamps and Open Collector output drivers.

Disconnect the Array and then the Battery Main Current connections followed by the battery sense connections. Connect the low current power supply to the battery sense connections in place of the battery. Reconnect the array and battery.

Slowly adjust the voltage upwards and note the value at which the high volts LED5 (red) turns "ON". Check that this can be adjusted with RV3. Connect a 1k Ohm resistor between 'BS+' and "HVA" and measure voltage between 'COM' and 'HVA'. With no alarm the voltage should be high and low when the alarm is present.

Slowly adjust the voltage downwards and note the value at which the Low Volts LED4 (red) turns 'ON'. Check that this can be adjusted with RV2. Connect a lk Ohm resistor between 'BS+' and 'LVA' and measure voltage between 'COM' and 'LVA'. With no alarm the voltage should be high and low when the alrm is present.

1.3 FAIL SAFE

The Fail Safe Circuit (TR1) is wired in series with the regulator shunt path (TR1 and the power resistor). In normal operation the fail safe is 'ON', that is always allowing current to flow. In the event of a fail to short circuit of the regulator, the fail safe will eventually turn 'OFF' (open) and force current to flow to the battery once more.

The fail safe voltage is set by RV1, buffered through ICI/a and temperature correction is applied by ICI/b which drives the following:

i) Power Device TR1
ii) Fail Safe in Operation indictor
iii) Fail Safe Operated indicator

Connect a voltmeter across 'FS' and 'NEG' and slowly reduce the battery sense voltage. Under normal operation the measured voltage should be near to zero. Check that this voltage rises nearly to battery volts and that LED6 (red) is 'ON' when the fail safe operates. Increase the battery sense voltage and check that the fail safe circuit automatically resets. Check the set point can be adjusted with RV1.

Check that LED7 illuminates at the same time as LED6 but that the alarm remains latched when the fail safe circuit is restored to normal operation. Check that the pushbutton SW1 resets the latch so that LED7 is 'OFF'.

Connect a 1k Ohm resistor between 'OP1' and 'BS+' and measure voltage betwen 'OP1' and 'NEG'. Voltage reading should be high during normal operation and low when the fail safe has operated.

Repeat for OP2.

INITIAL SETTING FOR INDICATOR LIGHTS

At 25'C.	Volts	Adjust with	
Regulation Start	14.4	RV1	Yellow LED2
Hi Voltage Alarm		RV3	Red LED5
Lo Voltage Alarm	12.5	RV2	Red LED4
Fail Safe Operation	12.5	on fail safe board	Red LED6

APPENDIX C

SPECIFICATIONS

3.0 SPECIFICATIONS:

Voltage: 12 volts DC Nominal
Amps: 5 amps
Battery type: lead acid
Inputs: Temperature sensor +
Temperature sensor -
Battery current +
Battery current -
Battery voltage sensor +
Battery voltage sensor -
Array current +
Array current -

Waterproof gland entries for:

A.	Tempsense cables provided	16GA X 2
B.	Battery current cables	12GA X 2 SOW
C.	Battery voltage sense	16GA X 2
D.	Array Current cables	12GA X 2 SOW

Housing: Housing is a stainless steel NEMA4 enclosure for water and corrosion resistance with special silicon gasket for extreme operating temperatures of - 60deg. C. to + 60deg. C.

Wall Mounting type: - 4 - 5/16 " mounting holes - two on top and two on bottom 14 3/4 inch lower holes spaced 10 " apart.

Enclosure size: 14 x 12 x 8

Weight: Net: 20 lbs. (9 kg.)
Shipping: 37 lbs. (17 kg.)

Shipping Dimensions: